NOTE

PINUS RADIATA PLYWOOD: INFLUENCE OF PANEL WIDTH AND LOADING METHOD ON BENDING PROPERTIES

H. BIER
Forest Research Institute, New Zealand Forest Service,
Private Bag, Rotorua, New Zealand

(Received for publication 2 July 1984; revision 26 July 1984)

ABSTRACT

Pinus radiata D. Don plywood panels of two constructions and four different widths were tested in third-point bending over a span of 1050 mm. No significant difference was found between moduli of rupture for the different widths. An ASTM centre-point bending test was carried out on 50-mm-wide specimens cut from the panels. It was found that the moduli of rupture of these specimens tested in third-point bending were significantly lower than the ASTM test values. Moduli of elasticity were similar in all tests.

INTRODUCTION

The effect of depth or volume on the strength properties of structural timber has been recognised by the inclusion of a size factor in design codes. In recent testing of plywood it was observed that the moduli of rupture of clear in-grade bending specimens 600 mm wide were lower than those of 50-mm-wide specimens (Bier 1983a, 1984). Different test methods were used for the two widths. The in-grade specimens were tested in third-point bending over a span of 1050 mm and the 50-mm specimens (obtained from the same panels as the wide specimens) were tested according to ASTM D3043 Method A (ASTM 1981) – centre-point bending over a span of 48 times the plywood thickness (i.e., 720 mm for the 15-mm plywood tested).

The question arose as to whether the difference in strength was due to specimen width, loading geometry, or both. Overseas investigators have studied the width effect and reported an increase of 28% in the strength of tension specimens and a decrease of 7% in the strength in bending of specimens for a width reduction from 250 mm to 50 mm (Linkov & Boitemirova 1981). The plywood used in that work was made from thin veneer cut from slow-grown material. *Pinus radiata* is a fast-grown species in New Zealand, with wide bands of earlywood and latewood which can effect the properties of small specimens. It was therefore necessary to evaluate both size and loading geometry in the present study.

METHOD

Specimens 600, 300, 150, and 50 mm wide were cut from each of 18 sheets of 15-mm-thick 5-ply plywood and 17 sheets of 21-mm-thick 7-ply plywood manufactured from clear veneer bonded with phenol formaldehyde resin (ICI P101). These specimens were tested in third-point bending according to the method described by Bier (1983a). A further 50-mm specimen from each panel was tested according to ASTM D3043 Method A and described by Bier (1984). Panel properties (modulus of rupture and modulus of elasticity) were calculated using the relationships 1 and 2 in Table 1.

RESULTS AND ANALYSIS

To allow for the lesser contribution of the plies perpendicular to the face grain, all comparisons were made using veneer properties calculated from the relationships 3 in Table 1.

TABLE 1—Equations for the calculation of bending properties

Third-point bending	ASTM Centre-point bending
1. Modulus of Elasticity	
E_{panel} apparent $= \frac{5}{27}\frac{W L^3}{\Delta b t^3}$	E_{panel} apparent $= \frac{P L^3}{4 b t^3 y}$
E_{panel} true $= \frac{1}{36}\frac{W L^3}{\delta b t^3}$	
where W is the total load	
2. Modulus of Rupture	
$R_{panel} = \frac{W max L}{b t^2}$	$R_{panel} = \frac{2}{3}\frac{P max L}{b t^2}$
3. Conversion to veneer stresses assuming $E_{parallel}/E_{perpendicular} = 20$	
(a) 5-ply $R_{veneer} = R_{panel} \times 1.2463$	
$E_{veneer} = E_{panel} \times 1.2463$	
(b) 7-ply $R_{veneer} = R_{panel} \times 1.3774$	
$E_{veneer} = E_{panel} \times 1.3774$	

Width Effect

To determine the effect of width, the results from the four specimens from each panel (block) were compared using a randomised complete block analysis of variance. The mean values for veneer moduli of rupture and moduli of elasticity are given in Table 2. No significant difference attributable to width was observed in strength values.

A Student Newman Keuls test showed that, statistically, the 50-mm 5-ply modulus of elasticity was significantly lower at the 5% confidence level than the values for other

TABLE 2—Mean values of veneer properties for plywood of different widths in third-point bending

	No. of specimens	Width (mm)			
		50	150	300	600
5-ply modulus of rupture (MPa)	18	60.81	61.62	62.05	62.31
7-ply modulus of rupture (MPa)	17	67.54	67.25	66.17	66.27
5-ply modulus of elasticity (true) (GPa)	18	12.32	12.81	13.34	12.95
7-ply modulus of elasticity (true) (GPa)	17	13.34	14.10	14.40	14.04
5-ply modulus of elasticity (app) (GPa)	18	11.14*	11.95	12.24	12.07
7-ply modulus of elasticity (app) (GPa)	17	11.52	12.12	11.88	11.92

widths. This was contrary to expectations but the value was within 6% of the grand mean and 8% of the mean for the other three widths (12.09 GPa) and the difference is of little consequence in practice. Further, there was no significant difference between values of the true modulus of elasticity for the different widths.

The analysis indicated a difference between the 5-ply true and apparent moduli of elasticity. The true modulus of elasticity is calculated from deflection in the pure bending zone between load heads (δ). The apparent modulus includes a shear component and is calculated from the deflection between support and load points (Δ). This can be compared with the values from the midpoint loading tests calculated from total deflection (y).

Loading Method

To determine the effect of loading method on the test results, the data from the 50-mm-wide third-point bending test were compared with the 50-mm-wide ASTM test data using a paired t-test.

There was a statistically significant difference between the apparent moduli of elasticity for the 5-ply but not for the 7-ply. However, the value of that difference is small (7%). The 5-ply mean for 50-mm width was also low in comparison with the apparent moduli of elasticity for the 150-, 300-, and 600-mm widths tested in third-point bending. It is practical to assume that the modulus of elasticity is similar for both loading methods.

The moduli of rupture were significantly different at the 1% confidence level (Table 3).

The lower strength value resulting from the third-point bending test is consistent with there being a substantially greater portion of the specimen subjected to maximum moment than in the ASTM test. This leads to a higher probability of failure.

From Table 3 we can determine that the ratio of the strength in third-point bending to the ASTM centre-point bending strength lies between 0.70 and 0.81 for 5-ply and 0.79 and 0.93 for 7-ply.

This compares with a value of 0.71 for 5-ply determined from regression analysis on tests of 116 panels of plywood as reported earlier (Bier 1983b). A direct comparison in that paper between 15 clear panels 600 mm wide and small clear specimens cut from the same sheets gave a value of 0.67.

TABLE 3—Mean values of veneer properties for 50-mm-wide plywood in third-point bending and centre-point bending (17 specimens)

	Centre point (ASTM D3043)	Third point	Confidence interval of difference
5-ply modulus of rupture (MPa)**	81.7	61.3	20.4 ± 4.5
7-ply modulus of rupture (MPa)**	78.4	67.5	10.9 ± 5.6
5-ply modulus of elasticity (GPa)*	11.98	11.19	0.79 ± 0.70
7-ply modulus of elasticity (GPa)	11.75	11.52	—

* significantly different at 5% level

CONCLUSIONS

There is no significant width effect in testing plywood in third-point bending over a span of 1050 mm.

The modulus of rupture of plywood tested in third-point bending over a span of 1050 mm may be as low as 67% of the ASTM value for 5-ply and 79% for 7-ply *P. radiata* plywood. Caution is required when predicting in-grade strength of large panels from small-clear test results.

ACKNOWLEDGMENTS

The assistance of D. Gaunt with the testing and M. Kimberley with statistical analyses is gratefully acknowledged.

REFERENCES

ASTM 1981: D3043-81, Standard Methods of Testing Plywood in Flexure. American Society for Testing and Materials, Philadelphia.

BIER, H. 1983a: Radiata pine plywood - An experimental study of the bending properties of structural plywood. **New Zealand Forest Service, FRI Bulletin No. 53.**

——— 1983b: Radiata pine plywood - A theoretical prediction of the bending properties of structural plywood. **New Zealand Forest Service, FRI Bulletin No. 54.**

——— 1984: Radiata pine plywood - The strength properties of small clear specimens of plywood. **New Zealand Forest Service, FRI Bulletin No. 83.**

LINKOV, I. M.; BOITEMIROVA, I. N. 1981: An investigation of the influence of the scale factor on the bending and tensile strengths of plywood. [Translation from Derevoobrabatyvayushchaya Promyshlennost 1981, No. 2].